Surface Operations Concepts: A Rover Demonstration of Sample Acquisition and Radio Antenna Deployment

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Objective

To demonstrate **disparate** surface **science activities** on the lunar farside **using a minimalist robotics platform**:

a) Sample acquisition and return (or collection) and

b) Deployment of an array of radio antennas for Cosmic Dawn science

Summary

Surface rovers offer expanded mission potential, such as:

- **Sample acquisition and return:** acquisition of a range of spatially distributed samples, returning and loading samples into an ascent vehicle
- **Radio antenna deployment:** distributing an array of antennas on the lunar surface for heliophysics or astrophysics observations

Using JPL's Axel rovers we demonstrated a mission concept:

- Used the JPL Mars Yard as a Lunar surface analog.
- **Acquired rock samples** with a percussive drill:
  - Supplied by Honeybee Robotics, the drill had previously been demonstrated acquiring powder samples from various rocks
- **Deployed two 5 meter antennas**
  - The metallicized polyimide film had previously been demonstrated as a proof-of-concept radio antenna
- **Operated semi-autonomously** with comms latency:
  - 1 s latency added to simulate deployment astronauts would experience in the cis-lunar environment

Axel Extreme Terrain Rover

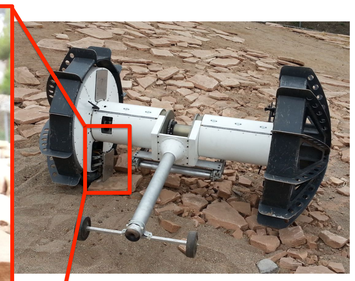
- Family of robotic platforms providing versatile mobility for:
  - Scientific access
  - Human-oriented exploration
- Design features:
  - **Modular** design with minimal complexity
  - **Symmetrical** design for robustness and redundancy
  - **Extreme terrain capable**, eg. steep or rocky terrains

Axel Rover descending cliff

Sample Acquisition & Return

- Terrestrial laboratories enable more detailed analysis of samples than *in situ* sensors. E.g.:
  - **Lunar rock samples** from Apollo are still studied today
  - **OSIRIS-REx** is an approved asteroid return mission
  - **Lunar South Pole-Aitkin Basin** mission concept identified as high priority in Planetary Decadal Survey
- Samples acquired from a diverse set of locations increases the value of the entire cache

Rock sampling with Honeybee Robotics percussive drill



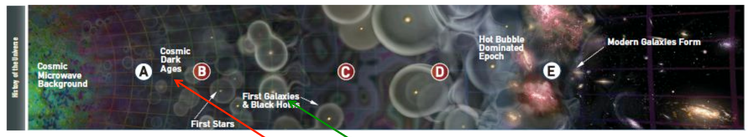
Two 5 meter metallicized film radio antennas deployed

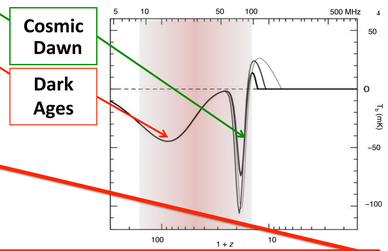
Benefits of Using Robots

- Provides a controlled approach for laying a thin metal film radio antenna on uneven lunar surface:
  - **Placement:** enables scouting landing site for flat terrain
  - **Scalable:** enables deployment of multiple antennas
  - **Configuration:** allows deployment of different configurations (e.g. star vs. array patterns)
  - **Controlled:** provides feedback during deployment to prevent tear or damage of delicate film
- Multiple disparate science goals using a single platform
  - Demonstrated antenna deployment and sample collection from rough terrain using Axel rover
- Enables human-in-the-loop monitoring and control of deployment process
  - Allows tuning during deployment
  - Can use semi-autonomous deployment from cis-lunar orbit with low latencies (a few seconds)

Radio Antenna Array Deployment

- **Radio observations** can address **key problems** in cosmology, astrobiology, heliophysics, and planetary science e.g.:
  - First light in the Universe (Cosmic Dawn)
  - Magnetic fields of extrasolar planets
  - Particle acceleration mechanisms
- **Cosmic Dawn** is a high priority science area as identified in the Astronomy Decadal Survey
- The **Moon** is a unique science platform:
  - Allows access to radio frequencies that do not penetrate the Earth's ionosphere
  - Its farside is shielded from intense terrestrial emissions
- An **array of antennas** will provide the largest science return:
  - Requires mobility on the scales of at least a few km





Radio antenna deployed from rover

Drawbacks of Using Robots

- Adds mass, complexity and cost:
  - Minimalist rover, such as Axel, alleviates this
- Requires additional communication infrastructure for human-in-the-loop control

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